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XIV. EXPERIMENTS

RESPECTING DEW, INTENDED TO ASCERTAIN WHETHER DEW
IS THE DESCENT OF VAPOUR DURING THE NIGHT, OR
THE PERSPIRATION OF THE EARTH, OR OF
PLANTS ; OR WHETHER IT IS NOT THE
EFFECT OF CONDENSATION.

By NOAH WEBSTER, Esq. F. A. A.



IN the summer of 1790, I took three pieces of paper of equal weight ; one I laid under a China saucer on the dry garden earth ; another was laid on the dry garden earth in the open air ; the third was placed on green grass under cover. In the morning the paper, which lay under cover, was covered with dew, as well as that, which lay in open air ; and that, which was on dry earth, under the saucer, was a little the heaviest. The dew on all of them was mostly on the under side next the earth, and stood or rather hung in small globules. The surface of the earth was dry, but as the season was rainy, the earth just below the surface was moist. The result of these experiments was, to prove dew to be the perspiration of the earth.

In July 1791 I made other experiments. The season was remarkably dry, and the earth at and near the surface retained very little moisture. I laid two China plates upon the dry surface of the earth, and in the morning found no dew on either of them. Yet the green vegetables about them were covered with a light dew. By this I judged, that the moisture of the earth was exhausted to such a depth, during the superior heat of the day, that no evaporation took place during the night, when the air was cooler. To satisfy myself in this particular, I made another experiment ; the state of the earth and air

being the same. I dug below the surface several inches, and turned up earth moderately moist, over which I placed a China fruit plate. It was ten o'clock at night, when I did this ; yet in the morning the under side of the plate was covered with dew, so that upon turning it up on one side, seven or eight drops of water fell from it. This served to confirm my opinion, that the reason why no dew appeared on the plates, laid on the dry surface in the former experiment, was, that the earth was so far exhausted by the extreme heat of the sun, that the heat of the night would not carry on evaporation from a considerable depth ; but when moist earth was placed at the surface, the evaporation was copious. On the same night, I placed another plate over a fresh leaf of a plant, the earth below being dry. In the morning the dew was considerable upon the under side of the plate, and it was visible upon the leaf, more especially on that part of it, which was a little removed from the earth. On that part of the leaf, which was in contact with the earth, the dew was scarcely visible. I was at a loss to determine from this experiment, whether the dew was perspired from the earth or the plant ; nor could I account for the appearance of more dew on that part of the leaf, which was a little raised from the earth, than on the other. I had repeatedly observed, that the under leaves of squashes, cucumbers, &c. were perfectly dry in the morning, when the upper leaves, which were open to the sky, were covered with dew. And from repeated examinations I found, that *both sides* of the leaf were alike, either dry, or moist with dew. When dew covered the upper side of a leaf, it likewise covered the under side, and when one side was dry, so was the other. This fact I believe to admit of few or no exceptions, and it deserves notice. For if dew is the perspiration of the earth, which some think probable, why should the under leaves next the earth be without dew, while the upper leaves at the distance of one or two feet from the earth are

covered with dew? And even the under side of such leaves, as moist as the upper side, when a direct ascent of the vapor is intercepted by the leaves below? I was led by these facts to suspect that dew may be partly, if not wholly, the effect of condensation by cold.

The first experiment indeed does not seem to favor the theory of condensation; for the papers under cover, and the China vessels themselves were moist only on the under side, or side next the earth. Now if dew is produced by the condensation of vapor, why should not the upper side of a vessel, which is exposed to the external air, and thus to a greater degree of cold, be the best condenser and consequently form the most dew?*

Perhaps the result of the second experiment may be however explained upon this hypothesis. At the time this was made, a severe drowth prevailed; the earth to a depth of five or six inches was almost totally exhausted of its moisture, and of course must have been heated during the day to a very considerable degree. Being thus heated and covered at sun set from the surrounding atmosphere, the earth under the plate might retain warmth enough during the night to prevent any condensation.

The third experiment differed from the second in two particulars, viz. in that the moist earth from below was brought up to the surface, and the plates were not laid over it until ten o'clock at night. In this case, the atmosphere, which cools immediately after sun set, had access to the earth more than two hours later, than in the second experiment; and perhaps this circumstance, with

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* Some remarks hereafter may solve this difficulty. The vapor *under* the plates is supposed to perspire from the earth, during the night, and to be warmer, when first emitted, than the air *above* the plates, in the open atmosphere; if so, then it is more condensable. The plates might not be cold enough to condense the cooler vapor above the plates.

the turning up of the moist and cool earth below the surface, rendered the air under the plates cool enough to make them condensers.

The fourth experiment may possibly favor the same theory, on a supposition, that a green leaf, which in summer is much cooler than dry earth, is a good condenser of vapor, and the better condenser at a little distance from the dry, warm earth, than near it, or in contact with it. But there are many other facts, within every man's observation, which strongly support the hypothesis, that dew is produced by a condensation of surrounding vapor. The copious moisture upon the outside of vessels, filled with cold water in hot weather, is certainly the effect of condensation, and is no feeble confirmation of the hypothesis respecting dew. The hoar frost is merely frozen dew, that is, vapor first condensed into water, and then frozen, or vapor congealed without condensation. This frost appears when the surface of the earth is sealed with frost, and of course the vapor, from which it is formed, cannot, at the time, perspire from the earth.

I have lately moved into a new house,* the plaistering of which was not thoroughly dry, when I came into it. When I arose in the morning, I observed a copious dew upon the glass windows of the keeping room, on the inside. The phenomena of this dew correspond exactly with those of the ordinary dew upon the earth.

In the first place the moisture upon the windows, which were exposed to the external air and the action of cold, was copious in clear weather, and sometimes would collect in such quantities, as to run down in drops. But at the same time glass within the room, as the looking glass, and the face of the clock, was perfectly dry. This was uniformly the fact for a number of nights successively. Hence the conclusion, that the exposure of the glass to the cold external air was

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* Written in December, 1791.

necessary to render it a condenser. Otherwise it is difficult to assign a reason why objects, in themselves equally cold with window glass, should not have been equally moist. In the second place, that glass, which was sheltered from the full effect of external air by outside shutters, was also dry. So striking was this phenomenon, that when one half of the external shutter was closed and the other half open, the half of the window, which was covered with the shutter, was perfectly dry, and that, which was exposed to the open air, was covered with a copious dew. And even when a single fold of the shutter was left open the glass exposed was moist, and the remainder dry; and *e contra*, when a single fold only was closed. These facts go a great length in confirming the hypothesis of condensation.

But thirdly, when the sky was overcast with clouds during the night, no moisture at all was visible on any part of the windows, though exposed to the external air. This fact, which appeared two or three mornings, but not in succession, as the sky was not clouded any two or three nights in succession, corresponds exactly with the phenomenon, which is within every man's observation, that a cloudy night produces no dew. This appears to me one of the most difficult and unaccountable phenomena respecting dew; and the fact now related totally overthrows the common solution of the phenomenon. The usual idea is, that in cloudy nights the vapor all ascends, and therefore none appears adhering to objects at or near the earth. But in the house, I am speaking of, the dew on the windows in clear weather proceeded from the damp walls, or inclosed air. Why should the same appearance fail in cloudy weather? The vapor could not escape from tight rooms and ascend to the clouds; at least, as great a quantity must have been thrown from the walls, and must have floated in the room in a cloudy night, as in a clear one. I suspect the reason for the phenomena, both in the house and in the open air, is,

that in cloudy weather the principle of condensation is wanting, whatever may be the cause. I state facts from repeated and uniform observation ; but I dare not in this instance undertake to assign the cause of their existence.

The foregoing facts were confirmed by the phenomenon, which took place after the season was so far advanced, that the dew on the windows would freeze, except one night, when some frost appeared on the glass, notwithstanding the sky was somewhat overcast. In all other respects the phenomena were the same. Wherever the glass was exposed to the action of the external air, though for a breadth of three inches only, there the inside of the glass was covered with a thin frost. But wherever the outside shutters shielded the glass, there was no frost or dew.

From these facts one is naturally led to conclude, that condensation is the principal, if not the sole cause of dew. If condensation is the sole cause of dew, then it depends on the same principle as distillation, or the condensation of vapor in the worm of a still ; as also on the same principle, with the dew on the outside of vessels, filled with cold water in a hot summer's day. If so, the inquiry is, whether a certain *fixed* degree of cold, in the air or object condensing, be necessary to form dew ? Or whether the degree of cold be only *comparative*, that is, in a certain proportion to that of the vapor condensed ? From such observations, as I have been able to make, I am inclined to believe the degree of cold *comparative*.

The water in the worm-tubs of common distilleries is taken from rivers, and not from wells. This water is considerably warmed in the tubs, yet is cold enough to condense the vapor, that rises from the boiling fluid in the stills. But the same degree of cold would by no means condense the vapor of the atmosphere in the hottest summer's day. Yet cold water, fresh from a deep well or spring, will condense it rapidly.

I remarked one morning in January, when the weather was very cold, the mercury in Fahrenheit standing at 12° below 0, that when I first rose, or about sun rise, the windows of my keeping room were perfectly free from frost. Soon after, a large fire being kindled, the glass of the windows was covered with a fine frost. This phenomenon is commonly ascribed to human breath; if this solution is just, it proves my supposition; for the breath issuing from the lungs is warmer than the air, and therefore more easily condensed. But this solution cannot be the just one; for the same phenomenon takes place, when no person is in the room. I rather ascribe it to the warmth communicated to the air by the fire, which renders the vapor more condensable.

Every person must have observed, that in extreme cold weather the glass windows of cellars collect frost on the inside. In a series of very cold weather in January 1792, I saw an instance of frost thus collected more than an inch thick. The vapor in the cellar, being comparatively warm, was of a temperature suitable for condensation.

I have a small room adjoining my office, which is kept shut; in which there is a window opposite to a chimney, at the distance of eight or nine feet. There is no fire kept in this room, nor does any person lodge in it; yet by means of a fire in an adjoining room, which communicates a degree of warmth to the inclosed air, the vapor becomes condensable, and in the morning this window is covered with dew, when no such phenomenon is visible in rooms not thus warmed.

Every person must have noticed the frost, shooting in the form of spiculæ through the little crevices, leading from cellars into upper and colder rooms. The comparatively warm vapor of the cellar, issuing, in extreme weather, through small openings into cold rooms, is immediately condensed and frozen.

We observe, that in hot weather dew is perceivable long before sunset. The laborer feels the moisture on his clothes and on the grass, while the sun is above the horizon. But I am doubtful whether the same phenomenon is observable in the morning, when the temperature of the air is the same. On the contrary, I suspect the dew *evaporates* in the morning, with a temperature of the atmosphere, in which vapor will *condense* in the afternoon. In the morning both the *air* and the *earth* are cool ; and as soon as the sun begins to warm the air and earth, a small degree of evaporation is begun. But when the earth has been heated almost to the temperature of blood, the water near the surface partakes of the heat. Soon after the warmest part of the day is past, the atmosphere begins to cool, while the earth retains the heat. The earth emits a *warm* vapor ; the atmosphere is *cooled* to a condenser. This is the distillation of nature ; and thus dew is formed. It seems to be the comparative coolness of the atmosphere, which renders the vapor condensable in the afternoon. This is the case also in the evening ; the earth retaining its heat longer than the air, and the warm vapor, constantly ascending into the cooler atmosphere, is speedily condensed. I suspect therefore, that a great portion of the dew, which is formed during the night, is composed of particles, that proceed from the earth *during the night*. So far then dew may be said to *rise*, and not *fall*. But it is the vapor in fact, which rises, in an *imperceptible* form, as during the day ; but in the night it is condensed, and *falls* ; whereas in the day time it continues imperceptible.

Perhaps these remarks will lead to a solution of the difficulty before mentioned, viz. the appearance of dew on *both* sides of the *upper* leaves of plants, while none appeared on *either* side of the *under* leaves. The upper leaves, being exposed to the direct action of the cold air,

were rendered *condensers* ; the lower leaves, being covered from the air, and near the warm earth, might not be rendered cool enough for that purpose.

After all, I would not speak with much confidence on these subjects, nor suppose that I have offered satisfactory solutions of the several phenomena. So far as I have stated *facts*, I trust my labors will not be wholly useless.